NGST Systems Engineering Report

Thermal Subsystem 02

Title:	
Updated Thermal Modeling Process using FEMAP, TSS, TCON, and SINDA85	
Date: 5/4/98	Number: THSER02
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References: 1. K. Parrish/GSFC, “Integrated Modeling Peer Review – Thermal,” presentation, 1-27-98	

Description

After the Fall 97 NGST Quarterly, a new thermal modeling process and analysis tools was adopted. The primary change in the process was the use of TSS instead of TRASYS and the use of FEMAP to reduce MSFC’s detailed thermal models to a size more compatible with top level thermal analyses

Modeling Process Overview

Thermal modeling of the NGST yardstick can be broken down into three separate areas. Detailed thermal modeling of the OTA is performed to provide temperature predictions for integration into the structural and optical performance analysis. Detailed thermal modeling of the ISIM is performed to examine detailed design and concept issues related to the instruments design. Top level system modeling, which consists of all of NGST’s major components, is performed to better understand broad thermal issues related to the entire observatory, to provide interface environments for the detailed models, and to examine various trades related to sunshield design and configurations. A variety of software thermal tools are used in this process. MSFC is responsible for detailed modeling of the OTA while GSFC undertakes system level and detailed ISIM analyses. Figure 1 illustrates and overview of the entire process.

As illustrated in Figure 1, GSFC creates the system level NGST thermal models based on ISIM, spacecraft, and sunshield, configuration options. Reduced models of the OTA, provided by MSFC are also included. Out put of this model consists of overall NGST system temperatures and thermal environments for detailed ISIM and OTA analyses. A reduced model of the GSFC sunshade along with it temperature breakdowns is provided to MSFC. Similar environments are provided for ISIM analysis.

MSFC utilizes the shade geometry and temperatures as boundary conditions for the detailed OTA analysis. Detailed OTA thermal models are create directly from the structural models of the OTA. Thermal nodes match structural nodes. Nodal temperatures from the detailed model are inputted directly into the structural models and thermal deformations are then calculated.

Modeling Software

Thermal Synthesis System (TSS). TSS, developed by NASA’s Johnson Space Center, is used by GSFC as the radiation solver of choice. Its robust Monte-Carlo ray trace techniques are used

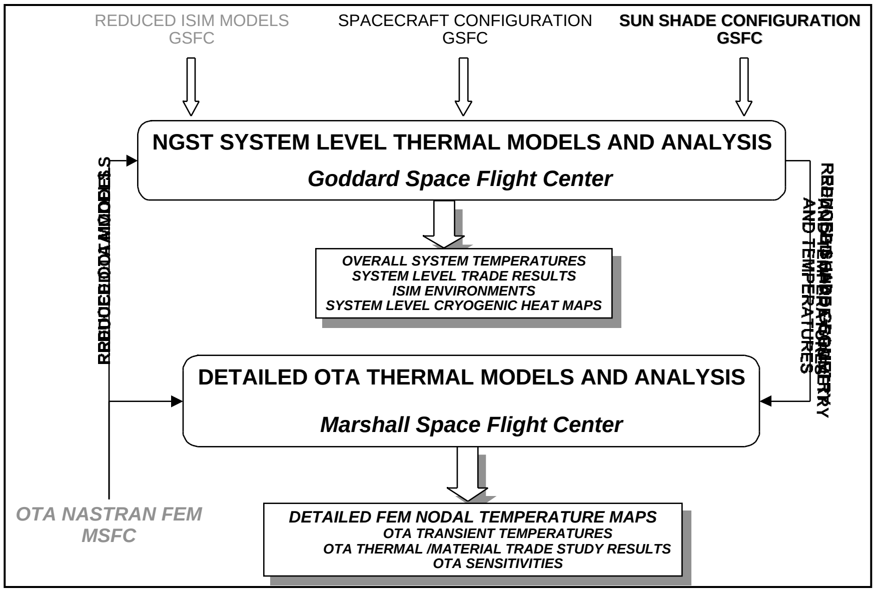


Figure 1 Thermal Modeling Process Overview

to calculate heating rates and surface radiation interchange factors. It is also used to build TSS is also used to calculated the conductance between nodes of the OTA. Although the OTA model is reduced for the system level model, OTA nodes still match the structural finite element nodes.

geometry and serves and a modeling pre and post processor. While TRASYS is also used for the same purposes, TSS has been found to more reliable and easier to use with accuracy.

SINDA85. SINDA85 is used as the thermal network solver

FEMAP. FEMAP, by Enterprise software, is used as a geometry builder, and FEM pre and post processor. Thermal models can be created from the structural FEM using FEMAP and TCON.

TCON. TCON, by Fred Costello Inc., is used to take a FEMAP neutral file and convert it into a SINDA85 and TSS compatible deck. TCON also calculates nodal conductances and capacitances based on the material and property cards found in the structural FEM.

Figure 2 illustrates the model conversion of a MSFC provided OTA FEM to a TSS and SINDA85 model.

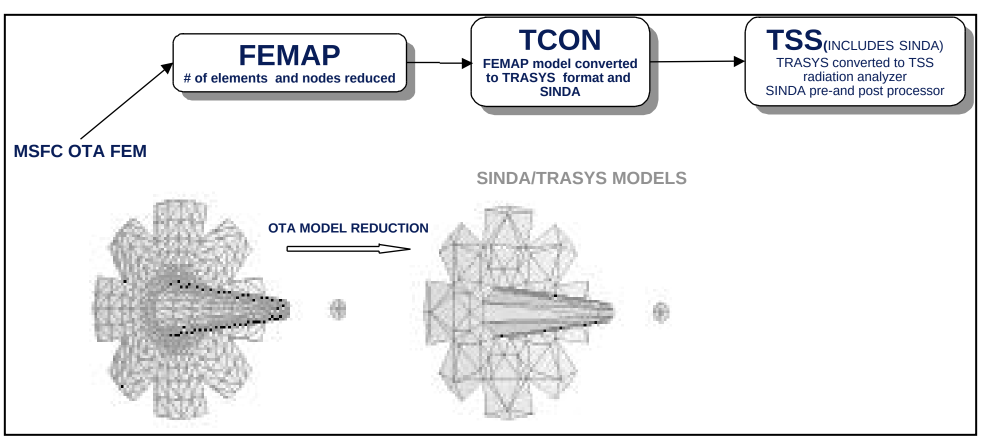
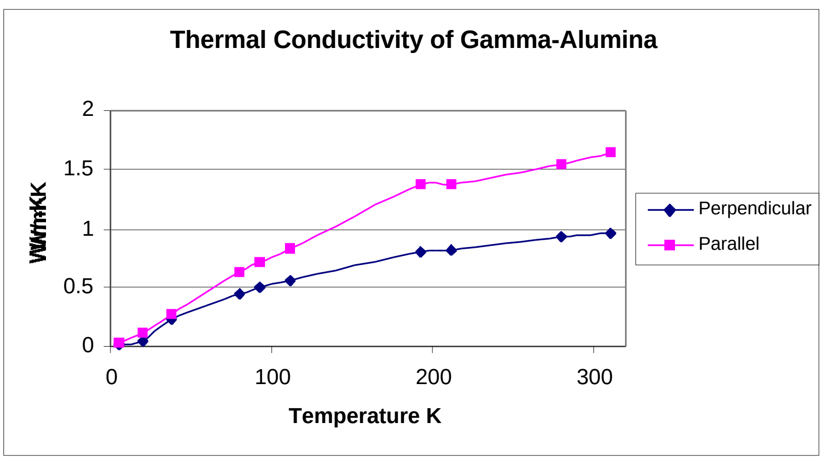


Figure 2 Detailed FEM Reduction for System Model

MSFC in house code. MSFC has developed in house software for transforming a detailed finite element model into a thermal model with node to node correspondence. In short, an additional thermal node is added to the geometric center of the finite element and conductances are calculated between each of the nodes. The new center node in turn acts as a convenient location to place to impose any heating and surface radiation interchange factor. This process allows detailed temperature mapping onto the structural finite element model.

System Level Modeling Assumptions

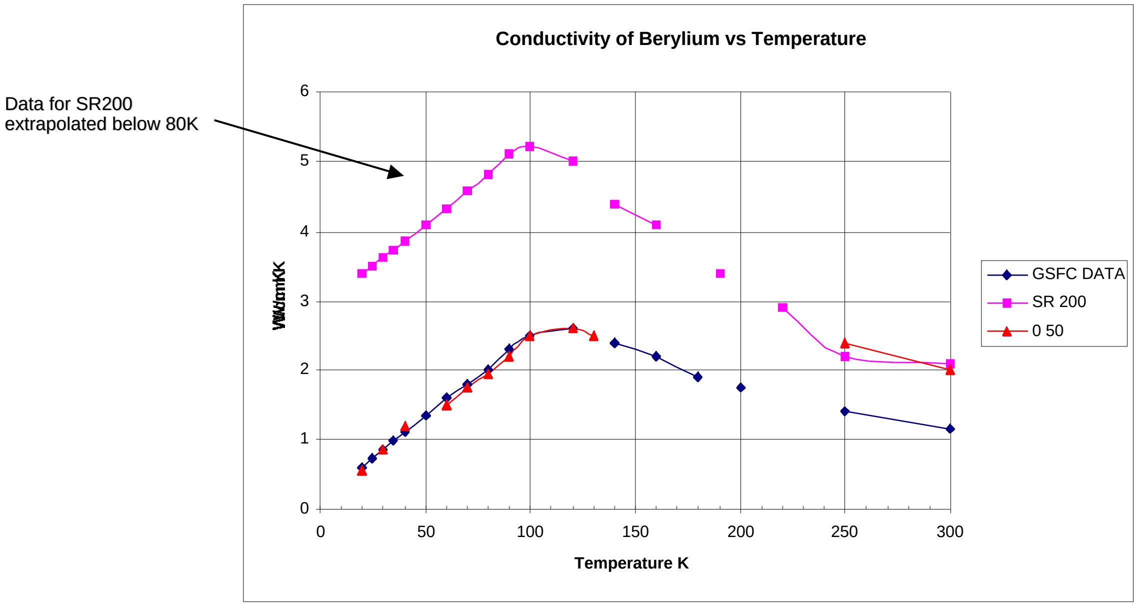
Material Properties. At this point in the NGST thermal studies only a limited amount of materials are considered. The most important material parameter is the thermal conductivity of the beryllium and graphite epoxy composites used in the primary mirror and OTA structure. The other conductivity of interests is of the material used in the isolation truss between the OTA and spacecraft. Gamma alumina, an aluminum oxide composite material with very low thermal conductivity, is assumed for the isolation truss. As Figure 3 illustrates although the conductivity of gamma alumina beneficially goes down with temperature, a room temperature value of 1.0 W/mK is assumed for the truss. Figure 4 shows the conductivity of representative grades of beryllium versus temperature. To simplify modeling, a fixed conductivity of beryllium of the SR200 at 35 K is assumed. This is felt to be conservative when considering optical performance as the lower conductivity value at 35 K should induce higher temperature gradients within the primary mirror's petals. Since graphite composite conductivity values vary widely depending on the type of fiber used, a baseline value of 1W/mK is currently assumed. This is an extremely low value which inhibits heat flow within the OTA and results in higher thermal gradients. As the design of NGST progress and candidate composites are identified, more realistic values for conductivity can be introduced. At this point, it is imperative that all material values be conservative, as to their



Rule/Sparks Test Data, NIST, Colorado, 1989, NISTR 89-3914

Figure 3 Thermal Conductivity of Gamma-Alumina

influence on overall system level performance. Table 1 summarized the conductivity values used in both system level and detailed OTA thermal modeling. The thermal capacitance of beryllium used for the transient analyses using the detailed OTA model is also listed. Titanium, used in the primary mirror actuators, and copper used in harnessing calculation is also listed. A NGST material specific database is planned which will compile thermal conductivities and capaciatances at cryogenic temperatures.



050Brush Wellman, SR200 - GSFC TESTING

Figure 4 Thermal Conductivity of Beryllium

Material	***Conductivity***	***Thermal Capacitance***
beryllium @35K	***100.0 W/cmK***	***34.1 J/kg-K (@60K)***
titanium(max. at ~40K)	***4.22 W/mK***	
graphite epoxy	***1.0 W/mK***	
gamma-alumina	***1.0 W/mK***	
Copper, OFHC at 35K	***1100 W/mK***	

Table 1 Thermal Material Properties Used in Analyses

Thermo-Optical Properties. As with the material properties, the number of thermal optical properties used currently is limited to simplify system level and detailed OTA analyses. As design details mature, actual optical properties will be included in the modeling. The most important surfaces of consideration for system trades are the coatings on the sunshield and OTA. Since the OTA will be operating at cryogenic temperatures high emittance values are limited to 0.7 until low temperature testing of candidate coatings proves otherwise. Low emittance surfaces on the OTA and sunshield have been baselined at 0.03. Of particular importance is the sunshield sun facing coating. Until candidate sunshield materials and coatings are qualified for the specifics of NGST's mission, the EOL optical properties for bare/ITO Kapton are used on the sun facing side. This also adds conservatism to the analyses, since both the spacecraft bus and OTA will benefit greatly from a less absorbing, higher emitting sun facing coating. Other optical properties of other candidate coatings, although not currently used in the analyses, are listed in Table 2, along with the properties currently assumed. As with the material properties, a comprehensive database of candidate coating optical properties down to cryogenic temperatures is planned for NGST.

Miscellaneous Modeling Assumptions. Baseline modeling assumes that NGST is on station at L2 with no thermal influence in the form of albedo or IR irradiance from the earth. At L2 only the sun provides environmental heating and the solar constant used for analyses is varied from 1291 W/m^2 for BOL to 1421 W/m^2 at EOL. The spacecraft bus is held at a boundary temperature of 20 C or 293 K. Another key parameter assumption is that all radiation between the sunshield layers is diffuse.

NGST Preliminary Thermal Analyses, Optical Properties, as of 12-22-97

ID	coating	α	$\varepsilon_{\text{hemispherical total}}$	BOL/EOL	STATUS	measured/estimated/source
01	GSFC Ag Composite	0.08	0.62	BOL	C	measured/GSFC
	GSFC Ag Composite	0.40	0.62	EOL (10 year)	C	estimated/no flight data
02	Kapton/ITO 0.5 mil aluminized	0.34	0.55	BOL	M	GSFC-TCC Database
	Kapton/ITO 0.5. mil aluminized	0.59	0.55	EOL (10 year)	M	GSFC estimated based on flight data
03	Kapton/ITO 1.0 mil aluminized	0.38	0.67	BOL	M	GSFC TCC Database
	Kapton/ITO 1.0 mil aluminized	0.63	0.67	EOL (10 year)	M	GSFC estimated based on flight data
04	VDA on Kapton	na	0.03	na	M	measured, GSFC TCC database
05	VDA on Kapton with rip stop	na	0.05	na	M,C	calculated, 2% ripstop area at ε= 1.0
06	black surfaces on cold side	na	0.07	na	P	placeholder for black surfaces at cryo-temps, paint, based on test data for Z307
07	beryllium	na	0.03	na	P	placeholder for polished and unpolished Be surfaces

C - candidate coating, part of test program on various substrates
M - mature material/coating
P - currently a placeholder for similar surfaces.

Notes
01 not currently recommended for preliminary thermal analyses, awaiting results from test program
02-currently the only recommended sun shade outerlayer material/coating for NGST
06-eventually, all cold side surfaces will need emittance vs. temperature test data

Other Notes
* Teflon, silverized or aluminized , is not currently recommended for use on NGST pending resolution/understanding of degradation experienced on HST

Table 2 Thermo-Optical Properties